Marine Physical Laboratory

Multi-Scale Studies of Seafloor Topography

Fred N. Spiess and Christian de Moustier
(Principal Investigators)

Final Report to the
Office of Naval Research
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Abstract

The long term goals of this research were to acquire and use spatially overlapping swath bathymetry data sets at different scales using multibeam echo-sounders, for use in characterizing the statistical nature of the deep sea floor in the contexts of marine geology and ocean acoustics. This work encompassed three areas: (a) construction of a deeply towed multibeam swath mapping sounding system that can be operated as a part of our Deep Tow system (Spiess and Lonsdale, 1982); (b) seagoing work to validate system capability, an initial expedition to use the system in the Pacific Natural Laboratory site (9° N, 104°-30′ W); and (b) subsequent data reduction and dissemination.

BACKGROUND

For nearly three decades, the Deep Tow group at the Marine Physical Laboratory of the Scripps Institution of Oceanography has built and operated instruments that were towed near the bottom at average ocean depths of 4 km. Over the past couple of years, inspired by a growing interest in high-resolution bathymetry and by the desire to investigate seafloor topography at a variety of scales, the group has developed a portable 100 kHz multibeam echo-sounder that is integrated with other

sensors in a new digital tow fish package capable of operations to 6 km depth. At present, the other sensors mounted on the fish are a pair of 110 kHz sidelooking sonars, a 23.5 kHz up-looking sonar, a 40 kHz obstacle avoidance sonar, a sonar for long-baseline navigation and an emergency transponder, a 4 kHz subbottom profiler, a Paroscientific pressure gauge, and a KVH fluxgate compass.

This fish is towed behind a ship at the end of a standard electro-mechanical oceanographic cable, 0.68" in diameter, to which it is directly connected through a slip-ring assembly. Digital data telemetry over 6 km of tow cable is reliable at 640 kbit/s and a 2400 baud modem connection between the computer inside the fish and computers aboard the ship enables control of the sensors and system parameters.

APPROACH

The multibeam sonar that we have developed can cover a 60^{o} swath at altitudes ranging from 20 m to 700 m above the bottom, with a horizontal spatial resolution equal to roughly 1% of the sonar altitude. The sonar transmits 100 kHz CW pulses (0.2 ms to 1 ms) on a line array, with a broadside beamwidth of 2^{o} by 57^{o}, that is driven by a single power amplifier and has a source level of 212 dB re 1 μPa @1m. Bottom echoes are received with an array of 44 hydrophones, whose long axis is perpendicular to that of the transmitter, yielding effective echo-sounding beam widths of about 2^{o}. The receive sensitivity of the individual hydrophone elements is -190 dBV, and their size dictated that they be spaced about 0.7 wavelengths apart. The hydrophone array is mounted directly on the end-cap of a pressure case containing the transmit and receive electronics, an A/D converter, memory and control logic for communication and data handling, and a two-axis clinometer for pitch and roll. Each hydrophone channel goes through a preamplifier with 50 dB of gain, an anti-aliasing band-pass filter centered at 100 kHz, a time-varying gain amplifier with 40 dB of dynamic range, and a sample-and-hold amplifier with unity gain. The latter is clocked to provide quadrature components of the based-banded signals. Such signals from the 44 hydrophones are multiplexed with analog pitch and roll signals, and then digitized by a 12-bit A/D converter and telemetered to the surface along with digital data from other sensors mounted on the fish.

At the surface, these data are logged to a 4mm DAT, and at the same time they are unpacked and passed to a MC56001 DSP computer which

performs gain and DC offset corrections on the individual hydrophone channels, followed by beamforming and echo detection operations. A 512-point complex FFT of each time slice across the 44 hydrophone is used to estimate arrival angles of seafloor echoes, yielding several hundred bathymetry points (up to a maximum of 512 points) across the swath for each ping. The corresponding magnitude data can be displayed as a sidescan raster line for subsequent output to a linescan recorder or to a grey-level strip chart on a CRT monitor.

ACCOMPLISHMENTS & RESULTS

The operational aspects of the system have been successfully tested at the end of April 1994 offshore San Diego, California, in 1500 m of water depth. Real-time bottom profiles were obtained at altitudes ranging from 20 m to 250 m above a sandy-silt bottom. Preliminary analyses of the data recorded during these tests indicate that the depth resolution of the system is about 0.3% of altitude in the athwartships plane. The angular accuracy of the bathymetric process implied by the wavenumber resolution is about 0.2^{o}. The along-track spatial resolution depends mostly on the accuracy of the fish navigation which is about 2 m rms for the Deep Tow long-baseline transponder navigation (de Moustier et al, 1994). Refinements in automatic bottom tracking functions, as well as optimization of gain settings, will have to be implemented for full survey operations.

IMPACT ON SCIENCE, TRANSITIONS

This project funded the Ph.D thesis work on signal processing for swath bathymetry of Duke University Graduate student Dimitris Pantzartzis. He defended his thesis in December 1994.

The sonar technology developed under this contract led to an exclusive license purchased by SEABEAM Instruments Inc. to build and market such a sonar system.

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C. de Moustier, F.N. Spiess, D. Pantzartzis, R. Zimmerman, R.M. Lawhead, F.V. Pavlicek, "First results from a Deep Tow multibeam echo-sounder", Proc. IEEE Oceans '94-OSATES, Vol. III, III.244-249, 1994.

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Satistical Information

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J.F. Gettrust and C. de Moustier, "Advances in seafloor mapping", MTS '94, Marine Tech. Soc., Sep. 7-9, Washington D.C., 1994. [Invited talk, Plenary Sessions]

C. de Moustier, F.N. Spiess, D. Pantzartzis, R. Zimmerman, R.M. Lawhead, F.V. Pavlicek, "First results from a Deep Tow multibeam echo-sounder", Proc. IEEE Oceans '94-OSATES, Vol. III, pp. III.244-.249, 1994. [Conference Proceedings]

D. Pantzartzis, C. de Moustier and D. Alexandrou, "Application of high-resolution beamforming to multibeam swath bathymetry", Proc. IEEE Oceans'93, Vol. II, pp. 77-82, 1993. [Conference Proceedings]

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GRADUATE STUDENTS: Dimitris Pantzartzis
PATENTS: SEABEAM Instruments Inc. has purchased an exclusive license to manufacture and market the Deep Tow multibeam echo-sounder designed, built and tested under this contract.
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